International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 17 (2018) pp. 13141-13145
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# Investigation of Effect of Machine Tool Vibration over the Surface Finish by Wavelet Transforms Technique

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**Abstract**

Surface roughness of machined component is very significant from the functional point of view of machined component. The surface finish is influenced by many factors such as machining condition, tool geometry and machining dynamics. There are numerous surface roughness parameters that are used to characterize the surface roughness in terms of $R_a$, $R_t$ and $R_Z$ by surface roughness measuring instrument. The analytical tools like Fast Fourier transform (FFT) and Wavelet transform (WFT) were currently used to correlate the surface finish more comprehensively. In this present work, attempts were made to study the influence of machine tool vibration on the surface finish in a turning operation. The influence of vibration on the surface can be studied by comparing the signals of surface and vibration using wavelet transform. The signal from machine tool vibration was captured by Digital storage oscilloscope through sensor and charge coupled amplifier in an Experimental setup. The data collected were analysed using Wavelet analysis in Matlab software. Significant correlation was found and recorded from the statistical analysis.

**Keyword:** Machine Tool vibration, Surface characterization, Wavelet transforms

## INTRODUCTION

The trends in manufacturing are towards tighter tolerances and higher performance standards that require close monitoring of the process. Thus, there is a need for finer bandwidths for process mapping and functional correlation. Wavelet analysis is becoming increasingly popular tools for filtering profiles in an efficient manner into multiple bands.

A typical engineering surface consists of a range of spatial frequencies. Historically, it has been accepted that different aspects of manufacturing process generate different wavelength regimes and these affect the function of the part differently. By separating surface profile into various bands it is possible to map the frequency spectrum of each band to manufacturing process that generated it or to the specific functional aspects of the part. Thus, filtering of surface profile serves as a useful tool for process control and functional correlation.

Far back in 1963, J.Peter et al have shown a positive correlation between vibration amplitude and surface roughness. M.C.Shaw (1983) lists the various causes for surface roughness apart from the feed mark. Some of these causes include (i) Varying un deformed chip thickness at secondary cutting edge (ii) Concentrated groove wear at the nose leading to replication of these groves on the work piece (iii) Side flow of chip at the trailing edge (iv) Built up edge (BUE) (v) imperfect cutting edge and (vi) Tool vibration

Investigation by T.Sata et al (1985) showed roughness profile of work piece is composed of several periodical components such as feed, spindle rotational error, vibration error etc. Studies by S.Moon et al (1994) showed that, the surface finish is significantly influenced by dynamics of Machining. Experimental result from S.C.Lin et al (1998) showed that, the surface topography is significantly influenced by relative motion between the cutting tool and work piece with the effect of tool Geometry affects the surface roughness. Exhaustive analysis of J.Raja et al (1995) correlated that multi scale decomposition of surface structure provides a significant amount of information that may be traced back to process.

Studies by Feng Xion et al (2001) showed that the wavelet transform is considered as mathematical microscope in the field of information processing of Engineering surfaces. In this current study we investigated the effect of machine tool vibration on surface texture during turning operation.

## MATHEMATICAL METHOD TO ANALYSE THE SURFACE TEXTURE

### Auto correlation function

It is one of the popular ways of representing spatial information of a surface profile. Treating the ordinates of the surface profile as time series, auto correlation (ACF), $\rho(\varsigma)$ is normalized Co-Variance Function ( Co-Variance Function (ACVF),The ACF can discriminate between differing spatial structures by its decay rate properties. The decay rate can also be represented by correlation length, the intercept where the ACF decays to zero and is a measure of average wavelength of the profile. Since many of the auto correlograms do not decay to zero, the profile is measured at $\sigma$ ($\varsigma$) =0.1 or 90% confidence limits (V.S.R.Murti etal, 2005).

### Discrete Fourier transform

It is well known from Fourier theory that a signal can be represented as the sum of a series of sines and cosines. However, sines and cosines that comprise bases of Fourier analysis are non local functions and have only frequency resolution and no time resolution. This means that although Fourier transform might be able to determine all frequencies present in the signal, it is unable to show when or where they are present. Localization implies a basic function has non zero value in finite domain. Wavelets overcome the shortcoming of sinusoids and impulses by having localization in both time and frequency domain to obtain resolution in both domains.

## Wavelet transform

In wavelet analysis, a signal is transformed to a series using a family of wavelet bases. Large scale bases represent low frequency components and small-scale bases represent high frequency components. The goal of wavelet analysis is to decompose a given signal over a family of wavelets, which is generated from mother wavelet by dilation and translation.

Many wavelet families with differing characteristics have been developed in the past decade.. The scaling function works as a low pass filter and the wavelet works as a band pass filter. Therefore, a primary consideration in applying wavelets for surface profile analysis is the amplitude and the phase transmission characteristics of the wavelet and the scaling function. Current standards such as the ASME B 46.1 on surface Texture specify non-linear phase as not desirable because it introduces distortion in filtered profiles. Thus a combination of good amplitude and linear phase transmission is always desired.

Different wavelet bases have different characteristics and can be chosen to satisfy specific surface conditions. If necessary, wavelet bases can be constructed to meet special requirements. Because current surface textures standards specify filters on the basis of their transmission characteristics, evaluating different wavelets in similar criteria is an essential prerequisite of surface texture analysis. **Bior6.8** is recommended in terms of transmission characteristics [Shengyu Fu etal, 2003]. The parameter comparison with ISO Gaussian filter shows good correlation with existing standards [Shengyu Fu etal, 2003].

## EXPERIMENTAL SETUP

**Figure 1.** View of Tool Holder, Insert & Sensor

Setup for vibration measurement consists of (i) Sensor, (ii) Charge Amplifier, (iii) Digital Storage Oscilloscope, (iv)Computer and (v) Data Capture Software.

Sensor used for vibration measurement is an accelerometer. The sensor is mounted to the tool holder by means of a mounting stud shown in Fig1. The mounting stud is of permanent bolt mounting type. Accelerometers are inertial measurement devices that convert mechanical motion to an electrical signal. This signal is proportional to the vibration's acceleration using the piezoelectric principle.

Oscilloscopes are data acquisition devices shown in Fig 2 used to translate an electronic signal into a pattern or waveform on a screen. As the waveform is traced across the screen, it creates a signature of the signal's characteristics .Digital includes high capacity hard disks, nonvolatile memory, and removable storage.

The Digital storage oscilloscope (DSO) is interfaced with the Computer using GPIB interface. The configuration of the computer used is usually of 256Mb ram, Intel processor, and windows operating system. The data capture software is supplied by the oscilloscope manufacturer. This software gives the waveform obtained on the DSO screen as digitized points in the file containing single or two columns.

**Figure 2.** Experimental Setup for Measuring Tool Vibration

## Sensor mounting

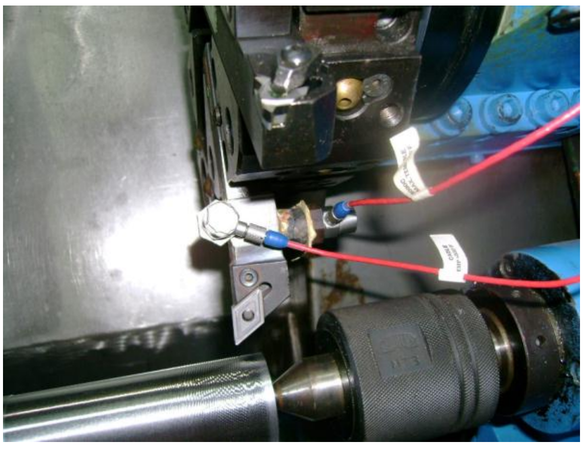

**Figure 3.** Close up View of the Sensor with Connector

Sensor is mounted to tool holder as shown in Fig. 3 with the help of permanent mounting stud. The sensor is connected to the charge (voltage) to AC conversion kit. The output from the kit is given to the oscilloscope. The oscilloscope is connected to the computer using GPIB interface. Data Capture software is installed in the computer. With the help of the software we can discrete the waveform (tool vibration) into1000, 2000, or 2million points.

## EXPERIMENTAL WORK

### Cutting Conditions for Experiments

Cutting Speed = 100m/min

Nose Radius = 0.8mm

Diameter of the Work piece = 40mm

| Specimen Reference | Feed(mm/rev) | Depth of Cut I(mm) | Depth of Cut II(mm) |
|---|---|---|---|
| R1 | 0.1 | 0.1 | 0.5 |
| R2 | 0.2 | 0.1 | 0.5 |
| R3 | 0.3 | 0.1 | 0.5 |

The specimen whose surface profile has to be measured is held in the chuck. The machine used is SPRINT 16TC turning center made by BatliBoi India Ltd. The insert used for turning is VBMT 16 04 08 coated carbide inserts. The tool holder used is left hand WIDAX SVHBR 2020K 16 tool holder.

The specimen is first given a skinning pass in the turning center. Then specimen is transferred to cylindrical grinding machine and is made perfect cylinder. Then again the specimen is transferred to the turning center.

The oscilloscope is calibrated by giving a known input. The oscilloscope is calibrated to 1ms in x-axis and 500mv in y-axis. The data capture software is also checked.

The experiments are carried out at constant cutting speed of 100 m/min and a depth of cut of 0.5 mm. Since the objective of the work is to study the influence of feed marks and vibration on the surface finish produced, the experiments are carried out at two feed rates and at three different overhangs of the cutting tool, which is expected to produce different tool vibrations. Altogether, a set of six machining experiments were carried out.

The specimen is turned with the above parameters as input for the turning operation in the turning center. When the tool starts to remove stock from the specimen vibrations are set to the tool as the tool is acting as a cantilever beam with one edge fixed to the turret and the other end doing the machining process. As machining process is carried out the speed of the spindle in rpm is noted from the machine for each experiment.

This vibration is measured by the sensor and transmitted to the charge to AC converter. This converter converts the charge output of the sensor to AC input for the Digital Storage Oscilloscope. The oscilloscope gives the tool vibration in the form of the wave with time in x-axis and voltage in y-axis. The oscilloscope is interfaced to computer through software.

With the help of the software the waveform in the oscilloscope is transferred the computer. Then the waveform is discretized using the same software to the required number of points. The digitized points can be saved in different formats, for example *.txt, *.csv, *.dat, etc. present work follows the waveform in digitized and saved in *.csv form for further data analysis. After the turning process is over oil is applied over the turned surface and sealed in an air tight cover. This is done to prevent corrosion of the turned surface. Surface profile of the turned surface has to be measured in the surface measuring instrument. Measuring instrument consists of a stylus that traverse along the measured surface, a mechanism to move the stylus, bed to place the specimen to be measured, and power supply. The instrument is interfaced with a computer, software for interfacing all supplied by the manufacturer.

The specimen protected by oil is removed from the air tight cover. The oil on the surface is swiped using a clean and soft cloth. The specimen is placed on a magnetic V-block and placed on the measuring bed. Now the software is invoked to establish an interface between the instrument and computer. Now the stylus is brought into contact with the surface to be measured with the help of the joystick which operates the stylus motion mechanism. An overload warning is given if the stylus is pressed too much onto the surface. The instrument should be calibrated first with known standard inputs.

The profile tracing process is started by clicking the start button in the software. The stylus starts to trace the surface profile of the specimen. The total measuring length for a single measurement is 2 mm, for every 0.001 mm distance traced the software take readings and display in the form of a profile.

After the measurement is over the profile has to be converted into digitized form. This is done by selecting the profile on the screen with the option make data points highlighted. The digitized profile is saved in the form of file with extension *.nc. It can be converted into *.csv format in the Microsoft excel workbook. The profile is preserved in the computer for further data analysis. Over the profile has to be converted into digitized form.

## ANALYSIS OF VIBRATION ON SURFACE TEXTURE

The following procedure is used to correlate the effect of vibration on surface texture using Matlab software in Wavelet module.

1. Load the surface profile data and vibration signal data from Wavelet tool box.
2. Decompose the surface signal to fifth level, which have one approximation and five details in wavelet analysis as shown in Fig4.
3. Decompose the vibration signal to second level, which have one approximation and two details in analysis as shown in Fig5.

4. To compare the signal apply statistical tool on the wave menu for surface and vibration signal to the required level of detail.
5. Apply Statistical tool to the level 2 (reconstructed detail) for surface signal as shown in Fig 6.
6. Apply Statistical tool to the level 1 (reconstructed detail) for vibration Signal as shown in Fig7.

| Statistical parameter | Surface signal | Vibration signal |
|---|---|---|
| Mean | $2.041\text{x } 10^{-6}$ | $2.261 \text{ X}10^{-6}$ |
| Median | $5.332 \text{ X } 10^{-5}$ | $4.927 \text{ X}10^{-5}$ |
| Range | 0.03377 | 0.05033 |
| Std. deviation | 0.003456 | 0.007256 |

By comparing the results of this parameter ensures the positive correlation between surface and vibration during machining process.

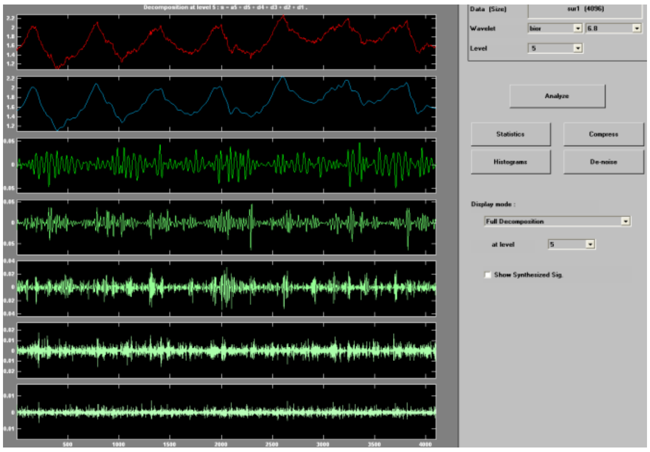

**Figure 4.** Surface texture decomposition at level 5 using Wavelet tool box

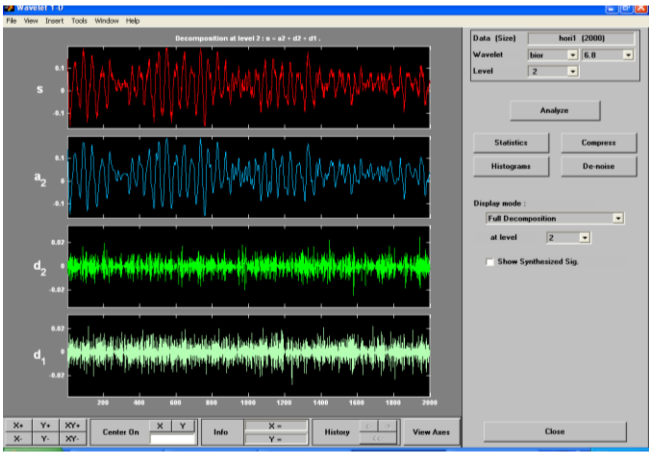

**Figure 5.** Vibration signal decomposition at level 2 using Wavelet tool box.

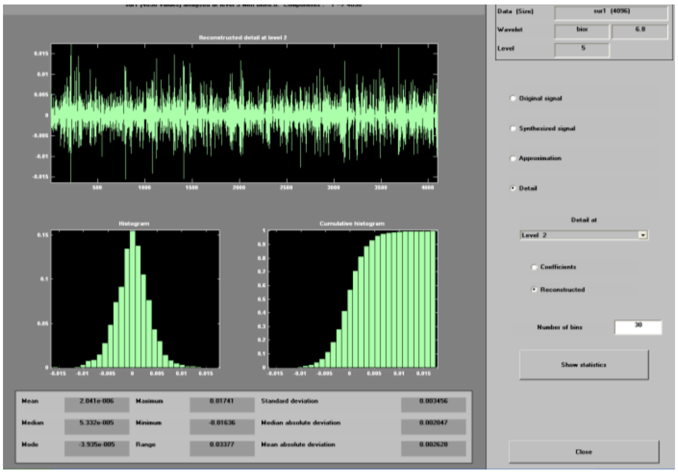

**Figure 6.** Statistics of Surface texture at level 2

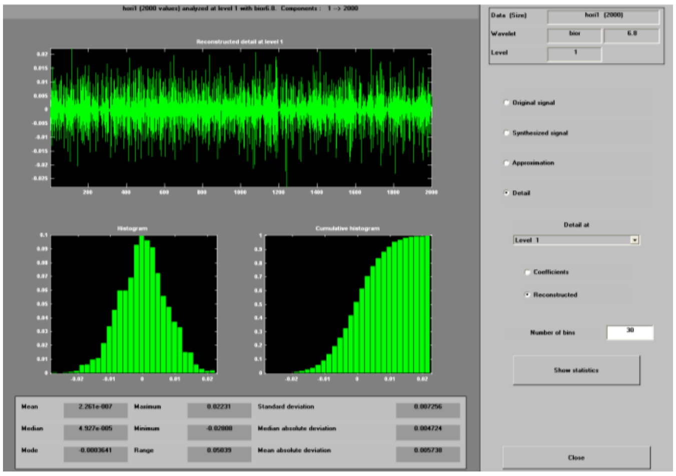

**Figure7.** Statistics of Vibration signal at level 1.

## CONCLUSION

It is clear that wavelet analysis is mathematical microscope to show the effect of vibration on surface feature during machining operation. The multi scale on multi resolution view of signal component provides a significant amount of information that may be track back to the process. In the present work a quantitative comparison has been made between vibration and surface by considering their statistical parameter**.**

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